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ABSTRACT

This review of the nutritional status of low-income preschool children in the United States discusses the topic in historical perspective and details current knowledge of the nutritional status of preschoolers. Discussion first focuses on the National Health and Nutrition Examination Survey II of 1976-80, and then turns to the National Food Consumption Survey of 1985 and studies of special subpopulations and of hospitalized children. Consequences of adverse nutritional status are discussed in terms of growth, health, malnutrition and infection, cognitive development, and obesity. Particular attention is given to iron deficiency. Subsequent discussion points out that nutritional status is clearly related to income. Poor children were observed to have poorer dietary intakes not in terms of the relative quality of their diets, but in terms of quantity. Other observations from five surveys revealed inadequate calcium, zinc, and vitamin A and C intakes among poor people in general and blacks in particular, and inadequate iron intakes for all income groups, particularly among blacks. Although the studies reviewed did not directly address program effects, articles that described improved nutrition status associated with participation in food programs were found. Approximately 150 references are cited. (RH)

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THE NUTRITIONAL STATUS OF LOW-INCOME PRESCHOOL CHILDREN IN THE UNITED STATES: A REVIEW OF THE LITERATURE

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For the

FOOD RESEARCH AND ACTION CENTER

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The Nutritional Status of Low-income Preschool Children:

A Review of the Literature

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About FRAC

The Food Research and Action Center (FRAC) works at the national and grassroots levels to alleviate hunger in the United States. Focusing primarily on improving the federal food assistance programs, FRAC's main activities include: acting as a clearinghouse on domestic hunger for a nationwide network of several thousand groups and individuals; monitoring federal policy developments on food assistance and hunger; providing technical assistance and training to legal services attorneys and anti-hunger activists; and educating the public and policymakers on the extent and causes of hunger and possible solutions to the problem. FRAC is a nonprofit, nonpartisan organization which relies primarily on the support of foundations, religious groups, corporations, individuals and others to continue its work on behalf of the disadvantaged.

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FRAC would also like to thank Dr. Jonathan Kotch, Associate Professor of Maternal and Child Health and Jo Shackelford, Research Assistant, of the University of North Carolina School of Public Health for their painstaking review of the current scientific literature on the nutritional status of low-income preschool children. Alan Sharpe, FRAC Senior Word Processing Secretary, assisted in the preparation of this document.

The Nutritional Status of Low-Income Preschool Children In the United States: A Review of the Literature

Introduction

In 1987, five million or 22.8 percent of children under age six were living below the poverty level. Even higher percentages of minority children lived in poverty -- 49 percent of all black children under age six and 41.8 percent of all Hispanic children under six. Moreover, the poor are getting poorer -- in 1987, 39.2 percent of the poor had incomes below half the poverty level, the highest percentage in more than a decade.

Living below poverty adversely affects the ability to purchase a nutritionally adequate diet. One can see these adverse effects in the local hunger surveys conducted in the 1980's which indicate a dramatic increase in the demand for emergency food and the use of emergency food facilities as a steady source of food over long periods of time. Food pantries and soup kitchens report that more and more families with young children are coming to them on a regular basis for food. FRAC's own on-going research on childhood hunger -- the scientifically tested Community Childhood Hunger Identification Project -- has documented a high prevalence of chronic hunger among low-income children in New Haven, Connecticut (18 percent) and three areas of Washington State (21 percent to 42 percent).

FRAC is especially concerned about the impact of this situation on preschool children. These children are usually not in school settings, so school breakfasts and lunches are not available to them. Aid to Families with Dependent Children, a program that benefits many of these children, generally has low benefit levels and recently has failed terribly in keeping pace with inflation. Many eligible low-income households are not participating in the Food Stamp Program, and even those who do have difficulty obtaining a nutritionally adequate diet with available resources. The Head Start Program and the Child Care Food Program, which provide nutritious meals and snacks to children in day care, reach a relatively small percentage of eligible children. And the WIC program, which provides nutritious supplemental foods to low-income women, infants and children age one to five years, reaches only 38 percent of the children who are estimated to be eligible for the Program, according to the most recent U.S. Department of Agriculture data.

Because of concern about the nutritional status of these children, FRAC asked Dr. Jonathan Kotch, Associate Professor of Maternal and Child Health, and Jo Shackelford, Research Assistant, at the University of North Carolina School of Public

Health, to review and analyze the scientific literature available on the nutritional status of low-income preschool children in the United States. What follows is a summary of their literature review, a listing of final conclusions, the literature review itself, and the references consulted.

The Nutritional Status of Low-Income Preschool Children In the United States

Executive Summary

HISTORY

Concern regarding the nutritional status of preschool children derives from both the immediate effects of inadequate diet and from its long lasting and possibly irreversible effects on health, growth, and development. Most interest in this subject has focused on the nutritional consequences of severe malnutrition in developing countries. While severe primary malnutrition is rare in the United States, deficiencies remain a concern in certain populations. Of equal or greater concern, however, is the possibility of more subtle long-term effects of chronic undernutrition and of overnutrition, both of which are common problems in the United States and other developed countries.

Until the late 1960's little was known about the general nutritional status of young children in the United States. However, in 1968 two federally funded national surveys -- the Preschool Nutrition Survey and the Ten-State Nutrition Survey -- took a more comprehensive look at the problem. The Preschool Nutrition Survey found that the average dietary intake of poor children was lower than that of non-poor children, but nutritional quality of diets differed very little between children of different socioeconomic ranks. The authors concluded that lack of sufficient quantity of food was the problem for poor children, rather than nutritional quality. In other words, the kinds of foods they were eating were nutritionally sound, but they were not eating enough food. The authors also found that children who were short for their age tended to be poor and that low hemoglobin (a sign of iron deficiency) was highest among poor children. The Ten-State Nutrition Survey surveyed 80,000 people, 12,000 of whom were children less than six years of age. This survey also found that insufficient food was a problem among low-income preschoolers. Lower stature, weight, skinfold thickness, head circumference; less advanced skeletal and dental development; later maturation; and later attainment of maximum stature were all associated with lower per capita income.

In the late 1960's and early 1970's several studies were done of smaller groups of preschoolers. These studies also found that lower income children did not grow as well and did not have as favorable a nutritional status as higher income children.

The first National Health and Nutrition Examination Survey was conducted by the Department of Health, Education and Welfare between 1971 and 1974. The survey found that children below the poverty level were shorter, lighter and had smaller skinfold thicknesses than those above the poverty level.

CURRENT KNOWLEDGE

The Second National Health and Nutrition Examination Survey was conducted between 1976 and 1980. Children below the poverty level were found to be shorter, lighter and had smaller skinfold thicknesses than higher income children. Preschool children living in poverty had a higher prevalence of low blood iron levels.

There have been several recent studies of sub-populations that include low-income preschoolers. The Utah Nutrition Monitoring Project (1985) surveyed 1,020 families in Utah whose income was below 185 percent of the poverty line. Significant percentages of preschool children were found to consume less than two-thirds of the Recommended Dietary Allowances for a number of nutrients. Also, short stature for age (below the fifth percentile) was found among one third of the preschool children, and one-fifth were below the fifth percentile for weight-for-age. The Massachusetts Nutrition Survey (1983) of children age six months to five years 11 months found that short stature (being below the fifth percentile) (9.8 percent) and anemia (12.2 percent) were the most common undernutrition-related problems.* Other smaller studies reflect similar findings. Studies among hospitalized children, which included preschoolers, indicate that children who are seriously malnourished when they come to the hospital usually have not participated in the health care system. Their malnutrition is only discovered when they need acute medical care.

The Centers for Disease Control Pediatric Nutrition Surveillance System (PNSS) covers children enrolled in public programs including the Special Supplemental Food Program for Women, Infants and Children (WIC), the Early Periodic Screening, Diagnosis and Treatment Program, and publicly funded Maternal and Child Health clinics. (Because children enrolled in public programs may be better off than other children, these surveys probably underestimate nutrition problems.) In 1983 nutrition-related abnormalities were identified in 15.7 to 33.4 percent of the children. The most prevalent problem was short stature.

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*For comparison purposes, a normal population is only expected to have five percent below the fifth percentile in growth measurements, and the national rate of anemia among low-income preschool children is probably between six and eight percent.

Data from the 1986 PNSS indicate a declining prevalence of anemia among low-income children from 7.8 percent in 1975 to 2.9 percent in 1985. However, the authors state the PNSS uses very stringent cut-off values in defining anemia, compared to current medical practice, and thus may have underestimated the prevalence. They state that "the prevalence of anemia among children ages one to five years from low-income families in the mid-1980's probably is in the range of 6% to 8% based on less stringent cut-off values commonly used in clinical settings."

CONSEQUENCES OF ADVERSE NUTRITIONAL STATUS

GROWTH

Growth is the most widely used index in assessing nutrition in children. In healthy populations, individual variation in growth is primarily determined genetically. However, when growth lags behind genetic potential, environmental factors have a major influence. Among these are nutrition, socioeconomic status, and infection or disease.

Evidence from the National Center for Health Statistics data and data from other U.S. surveys show that undernourished children are often short in stature, and there is a clear relationship between family income levels and reduced height. Studies from other countries show similar results for samples of preschool children of the same ethnic population but different socioeconomic groups.

HEALTH STATUS

There is strong evidence that height and other growth measurements reflect the nutritional status of children. Moreover, studies in developing nations have documented increased morbidity (illness) and mortality associated with poor growth.

MALNUTRITION AND INFECTION

Infectious diseases occur more frequently, are more severe, and have longer duration in malnourished individuals. Malnutrition impairs the body's defense mechanisms in a number of ways. Most studies of the effects on immune response have involved cases of severe malnutrition. However, there is growing evidence that even mild to moderate nutritional deficits may adversely alter the immune response in a small proportion of undernourished children often before clinical signs of malnutrition appear.

COGNITIVE DEVELOPMENT

Most studies on the effects of malnutrition on cognitive development and behavior have focused on the outcome of severe malnutrition, but recently studies have been shifting to investigations of mild-to-moderate deficiencies. The effects of mild-to-moderate undernutrition on mental development may affect more children than severe malnutrition in both underdeveloped and developed countries. Evidence from intervention studies in developing countries that involve the provision of nutritious supplemental foods to children provides support for a causal relationship between nutrition and mental development.

SOCIAL BEHAVIOR

There have been fewer studies of the effect of malnutrition on social-emotional functioning than on cognitive development, but there has been a shift of emphasis recently. Researchers are reporting that even mild to moderate undernutrition produces increased apathy and reduces children's activity levels and exploratory behavior, which may in turn reduce the mother's responsiveness and enthusiasm toward the child. The child who doesn't elicit positive responses learns to withdraw from social contacts. This is of concern because development of social skills appears to be dependent on learned interaction skills in the earliest stages of childhood and on care-giver-child interaction. Mild-to-moderate malnutrition is far more prevalent, and would, therefore, put large numbers of children at risk of social dysfunction.

IRON DEFICIENCY: A SPECIAL CASE

Iron deficiency, which is relatively prevalent and easily measured, has been extensively studied for its effects. Current evidence strongly supports an association between iron deficiency, with or without anemia*, and behavioral symptoms of apathy, inattentiveness, irritability, memory difficulties, and lowered performance on cognitive tests in infants and preschool children.

LEAD LEVELS AND BEHAVIOR

Comparisons of cognitive and behavioral functioning of children with high and low lead levels reveal that high lead

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*Iron deficiency is defined as the decrease or disappearance of iron stores in the body. Iron deficiency anemia does not develop until all the storage iron has been used up and changes in the red blood cells result.

levels are associated with deficits in Intelligence Quotient (IQ), verbal IQ, auditory processing, and attentional performance. Children with high lead levels, even three years after being treated, spend more time in distracted, off-task behavior in the classroom. Lead and other heavy metals are absorbed by the body more readily when children are malnourished or anemic, and low-income children experience a higher risk of being both.

DISCUSSION

It is clear that nutritional status is related to income, and that relationship is in the expected direction. Poor children have poorer dietary intakes, not in terms of the relative nutritional quality of their diets, but in terms of the quantity of food they consume. Lower energy intakes among poorer children were observed by the Ten State Nutrition Survey as early as 1968, and again in the National Food Consumption Survey of 1985. Other observations among the national surveys included inadequate calcium, zinc, vitamin A and vitamin C intakes among the poor and/or among blacks, and inadequate iron intakes among all income groups, particularly among blacks.

In general, poor children tend to be shorter. In some cases the burden of short stature is excessive. In the Utah Project, for example, 33.3% of children below 185% of poverty fell below the fifth percentile for height-for-age, 28.3% more than expected. Similarly, poor children are lighter and less fat than non-poor children. There seemed to be no significant improvement in the gap in overall growth parameters between poor and non-poor preschoolers from the 1971-74 National Health and Nutrition Examination Survey (NHANES I) to the one carried out between 1976 and 80 (NHANES II).

Poor preschool children have greater rates of impaired hemoglobin and hematocrit levels, and poor black preschoolers have the most impairment. Between NHANES I and NHANES II, there was improvement noted in iron or hematologic status, yet significant impairment persisted. Similarly, elevated lead levels decreased from NHANES I to NHANES II, yet even by the time of NHANES II the incidence of elevated lead levels was as high as 18.5 percent among black, urban children.

In the case of iron status, most of the evidence suggests that impaired iron status, even in the absence of anemia, is associated with poorer performance on standardized tests, and that performance can be improved with iron therapy. Similarly, relatively recent studies in developing countries have produced evidence of an association between nutrition supplementation of mildly undernourished (as opposed to severely malnourished) preschoolers and improved social behavior. When mildly undernourished children were supplemented, they had better

attention spans, more persistence, less distractibility, more social interaction, less dependence and anxiety, better impulse control and happier affect. The net effect of these improvements resulted in better performance in novel environments, more involvement in competitive games, greater number of strategies attempted in response to a frustrating task, and fewer errors in structural impulse control games.

PROGRAM EFFECTS

The National Food Consumption Survey compared poor children on food stamps with those not on food stamps. Non-food stamp participants had inadequate levels of four nutrients, and food stamp participants had only two. However, one cannot conclude that food stamp participation caused the improvement because the survey was not set up to make that judgement.

In Memphis, researchers compared preschool nutrition status in 1977 with that in 1983 and noticed improvement in vitamin A and vitamin C intake, in hematologic status, and in obesity. These improvements were attributed to increased participation in publicly supported food and nutrition programs. Other smaller studies show similar nutrition and health impacts of food programs on preschool children.

There has been overall improvement in the iron status of preschool children between NHANES I and NHANES II. It is likely that this improvement is attributable to iron fortification of infant formulas and cereal products. Researchers at the Centers for Disease Control have noted important gains in iron status in several states participating in the Pediatric Nutrition Surveillance System. Observing that children already enrolled in the WIC program have better iron status than same-age children at their first WIC visit, the authors conclude that participation in WIC is also associated with lower rates of anemia.

CONCLUSIONS:

1. Nutrition studies and surveys among preschool children have consistently shown that nutrition problems are associated with low income.

2. The diets of low-income preschoolers tend to be adequate in nutritional quality, but insufficient in quantity, suggesting that if these children were able to consume more food of equal nutritional content, they would be better-nourished.

3. There is evidence that preschool children can suffer negative social and behavioral effects when they are mildly to moderately undernourished.

4. According to the local surveys reviewed, participation in food and nutrition programs is associated with improvement in nutritional status among preschoolers.

5. The only nutrition indicator that has significantly improved among low-income preschoolers between the 1971-74 National Health and Nutrition Examination Survey (NHANES I) and the 1976-1980 NHANES II is iron status. Yet, even with this improvement, a significant level of impairment persists, as does the difference in iron status between poor and non-poor children. While there appears to have been a general improvement in the growth of poor children from NHANES I to NHANES II, the differences do not reach statistical significance. Also, the gap between the growth indicators of low-income preschoolers and those of higher-income preschoolers did not change significantly between these two time periods. Therefore, growth differences associated with poverty, while improving, have not been eliminated.

The Nutritional Status of Low-Income Preschool Children: A Review of the Literature

I. Historical Perspective

Concern regarding the nutritional status of preschool children derives from both the immediate effects of inadequate diet and from its long lasting and possibly irreversible effects on health, growth, and development. Most interest in this subject has focused on the nutritional consequences of severe malnutrition in developing countries. While severe primary malnutrition is rare in the United States, deficiencies remain a concern in certain populations. Of equal or greater concern, however, is the possibility of more subtle long-term effects of chronic subclinical undernutrition and of overnutrition, both of which are common problems in the United States and other developed countries (Listernick, Christoffel, Pace, et al., 1985; Gayle, Dibley, Marks, et al., 1987; Merritt and Suskind, 1979).

Until the late 1960's little was known about the general nutritional status of young children in the United States. Studies of various segments of the population had been reported, but they were often limited in scope and sample size (Kelsay, 1969). In 1968 Hunger, U.S.A. was published by the Citizen's Board of Inquiry and widely publicized in the media. This report concluded that widespread hunger and malnutrition existed in many parts of the United States. Although not itself based on a scientifically conducted survey, the report led to a more comprehensive look at the problem through two national surveys, the Preschool Nutrition Survey and the Ten-State Nutritional Survey.

Owen's Preschool Nutritional Survey 1968-70

The purpose of the Preschool Nutrition Survey (PNS) was not to determine the prevalence of malnutrition or of specific disorders but to provide an "overview of descriptive data on nutritional status of a cross-sectional sample of preschool children in the United States" (Owen, Kram, Garry, et al., 1974). Aware that the Ten-State Nutritional Survey, which was in planning, would focus on poverty populations, the PNS felt that a cross-sectional approach was needed to compare subsets of the population. The samples included 3441 children from 74 sample areas in 36 states and the District of Columbia.

Considerable information about socioeconomic status, eating habits, current dietary intake, and medical history, and from physical examinations, and biochemical evaluations, was gathered on the participating children and their families. The survey found few specific nutritional deficiency disorders. In general, age and socioeconomic rank appeared to be the major determinants of health and nutritional status.

Dietary Intake: Average dietary intake of poor children was lower, but nutritional quality of diets differed very little between children of different socioeconomic (SES) ranks. The authors concluded that lack of sufficient quantity of food was the problem rather than quality. Supplements contributed substantial amounts of vitamins to total intakes of preschool children with greatest percentage increases for poor children. Protein consumption differed little by age, race, or SES. Calcium intake of black children was less than white, and a progressive decrease in use of dairy products was found with increasing age. Ascorbic acid intakes were 50% greater in upper SES groups representing a greater use of supplements and citrus fruits. Mean iron intake was higher for white children than blacks.

Anthropometry: Children short-for-age clustered in the low SES groups. Black children were smaller at birth. They were heavier and taller than white children at two years of age, but were thinner with less subcutaneous fat. Excluding blacks, there was a progressive increase of height, weight, and head circumference with increase in SES status.

Biochemical Values: An excess of "low or unacceptable" biochemical values clustered among children of lower SES. Hemoglobin values were lowest in lowest SES groups and increased progressively in each rank and in each age group. Mean hemoglobin was higher in whites than blacks in each age group. Transferrin saturation values, reflecting iron stores, were also higher in whites and increased with age. Vitamin A or plasma retinol levels were consistently higher in whites and generally increased with SES rank in association with greater use of vitamin supplements. Vitamin C levels were also higher in upper SES ranks and in white children.

Dental Examination: Children in low SES Groups and particularly black children had the highest dental caries attack rate (Owen, et al., 1974; Owen and Kram, 1968; Owen, Garry, Lubin, et al., 1971; Owen, Nelson, Kram, et al., 1969; Jones, Nesheim, and Habicht, 1985).

Ten-State Nutrition Survey 1968-70

In 1967 Congress directed the Department of Health, Education, and Welfare to undertake a survey to determine "the incidence, magnitude, and location of serious hunger and malnutrition in the U.S." (Garn and Clark, 1975; Shaefer, 1969). In response, the Ten-State Nutrition Survey (TSNS) was conducted with the sample disproportionately selected from the lowest socioeconomic sections of ten states. Data were obtained on 80,000 individuals with approximately 12,000 children less than six years of age participating. Information obtained included dietary recall, general SES data, physical and dental examinations, biochemical and anthropometrical assessments. The TSNS found that substantial numbers of children were undernourished and that smaller size was associated with lower income.

Dietary Intake: Diets varied with geographic locale, SES, race, and ethnicity, with energy intakes lowest for blacks and Mexican-Americans living in southern states. However, the nutrient quality varied little in relation to race or income except for Vitamin A. This is consistent with the PNS finding that the amount of available food is more a problem than quality of food. The total food intake of children in low-income families was limited, and this was reflected in their growth parameters. In all age groups iron was uniformly below dietary standards, and average daily intakes were similar regardless of SES.

Anthropometry: Greater stature, weight, triceps skinfold thickness, and head circumference; advanced skeletal and dental development; earlier maturation; and earlier attainment of maximum stature were all associated with higher per capita income. These differences were in large part established by the first year of life and were consistent thereafter. Black children, as in the PNS, tended to have advanced skeletal and dental development, earlier maturation, and a tendency toward greater body size. Median thickness of subcutaneous fat increased directly with income and continued through adolescence in males. However, in females the relationship reversed in adolescence with lower income girls being fattest. At all ages, black males were leanest; and after adolescence, black females were fattest with at least part related to low income. Obesity in children and adolescents, with its resistance to treatment and with potentially serious behavioral and health consequences, was identified as a common nutrition-related health problem.

Biochemical values: Hemoglobin levels were lowest in black children. Essentially all anemia found was due to iron deficiency, and a high prevalence was demonstrated in all ages. Vitamin A levels were lower in low SES groups living in southern states, with lowest levels in Mexican-Americans. Blacks and whites were similar in low values of plasma ascorbic acid, and

2/3rds of low levels were found in southeastern states (Garn and Clark, 1975; American Academy of Pediatrics, 1973; Schwerin, Stanton, Riley, et al., 1981; Jones, et al., 1985; Schaefer, 1969).

Subpopulation Preschool Nutrition Surveys of the late 1960's-early 1970's

Kerrey, Crispin, Fox, et al. (1968) conducted a survey of 40 preschool children, ages 3 1/2 to 5 1/2 years of age in Lincoln, Nebraska, half from high SES level and half from low SES level. All mean anthropometric measurements except skinfold thicknesses tended to be greater for the higher SES group. The mean calorie intake for both groups was slightly lower than recommended intake, and the most limited nutrients were iron, calcium, and ascorbic acid. In general, higher SES children had a more favorable nutritional status, partly attributable to greater use of vitamin supplements. Hemoglobin and hematocrit levels were comparable in the two groups.

Chase, Kumar, Dodds, et al. (1971) studied the nutritional and health status of 300 Mexican-American preschool children of migrant workers in Colorado in 1969. Vitamin A deficiency was a major problem in 55% of the children. Reduced calorie intake was suggested by the finding that 35% of the children were below the 10th percentile for triceps skinfold measurement. Height attainment was low in 54 of the 300 children. Vitamin C levels were also low in these same 54 children.

Zee, Walters and Mitchell (1970) surveyed 300 black children from poverty-level families in Memphis. Half of the children were below the 25th percentile for height and weight, and 28% of children less than three years of age were anemic (Hgb less than 10gm/100ml). The authors concluded that low amounts of available food were the main cause of growth retardation and anemia.

Driskell and Price (1974) studied the nutritional status of 40 preschool children (ages 2 to 5 years) from low-income families in Montgomery, Alabama, who received health care from a city-county clinic. Hemoglobin concentrations were below the acceptable level (11.0 gm) in 13% of the children and hematocrits were below acceptable level (34%) in 28% of the children. In general, individual nutrient mean intakes exceeded the recommended amounts except for calcium and iron. Mean heights and weights fell between the 50th and 75th percentiles reported by Owen's preschool nutritional survey (1968-70). Ten percent of the subjects fell below the 10th percentile for height and weight.

North Central Region
Infants and Preschool Nutritional Survey

The North Central Region (NCR) Survey was conducted in twelve contiguous states of the north central region of the United States. The study included information on family characteristics, nutrition education and attitudes of the mother, food purchasing practices, current and early feeding practices, health and physician status, food intake records, and data on family economic status. The sample included 3,444 children less than 72 months of age from predominantly middle income families. The survey found that children of all income levels had about the same calorie intake, but higher income children received higher protein, iron, ascorbic acid, and thiamine content. As found in previous surveys, the lowest income group's height and weight were less than higher income children. Education of the mother was a significant factor affecting quality of diet. Attitudes and child feeding practices in this area tended to emphasize overfeeding. The authors concluded there was an urgent need for broad-based nutrition education programs (Eppright, Fox, Fryer, et al., 1972).

The First National Health and Nutrition Examination Survey
NHANES I, 1971-1974

NHANES I was conducted between 1971 and 1974 to measure the health and nutritional status of the U.S. population and to monitor changes in this status over time. The survey was the first to utilize a scientifically designed probability sample, which permits estimates for the total population and at the same time permits analysis of groups such as preschool children at high risk for malnutrition (Lowenstein, 1981). Altogether, 20,749 individuals ages one through 74 years, including 4,952 children ages one through 11 years, were examined. The nutrition component of the survey included sociodemographic data, a dietary recall questionnaire, health history and physical examination, and anthropometric, hematologic, and biochemical measurements.

Dietary Intake: The reported energy intakes from 24 hour dietary recall showed very few differences between poor and non-poor children and could not account for the differences in growth. The mean intake of each nutrient by the total black population was below that of the total white population, but both were at or above RDA standards for all nutrients except dietary iron. Mean iron intake was equal to or less than 50% of standard for children ages 1-4 years. In the 4-11 age group 81.6% white children and 82.8% black children reported iron intakes below standard on the day of dietary recall (Jones, et al., 1985; Kerr, Lee, Lorimor, et al., 1982).

Anthropometry: The survey found that children in income groups at or above poverty level were consistently taller, heavier, and had greater triceps skin-fold thickness measurements than those below poverty level. Black children were taller than white children. (Jones, et al., 1985; Kerr, Lee, Lorimor, et al., 1982).

Biochemical Values: NHANES I data identified few deficient biochemical values, but a large number were considered low. Whether these represent abnormal states or the low end of the distribution for a well-nourished population was difficult to determine (Kerr, Lee, Lam, et al., 1982).

Black subjects had lower mean hemoglobin, hematocrit, and transferrin saturation values than whites in each age group. The youngest children, ages 1 to 3, had the highest percentage of low hemoglobin, serum iron, and transferrin saturation values (Jones, et al., 1985). In the 4-11 age group the percentage of the population below standard in the following values were hemoglobin: 5.5% white, 21.1% black; hematocrit: 18.3% white, 29.4% black; transferrin saturation: 30.0% white, 33.7% black; serum iron: 8.2% white, 8.0 black (Kerr, Lee and Lam, et al, 1982).

II. Current Knowledge of the Nutritional Status of Preschoolers

National Health and Nutrition Examination Survey II NHANES II, 1976-1980

The NHANES II Survey was designed to provide health and nutritional information for the civilian, noninstitutionalized population of the U.S., ages six months to 74 years of age, and specifically, to describe changes in status occurring since NHANES I. A stratified multistage probability sample identified approximately 20,300 individuals for the survey including 7,011 children ages six months to 17 years. Those groups considered to be at risk for impaired nutritional status were overrepresented to improve statistical reliability of the data for them. These included young children, those below poverty level, and the aged. The protocol included questionnaires on demographic variables, medical history, diet, and use of medication and dietary supplements; medical examination; and special clinical procedures including anthropometry and biochemical assessments.

Dietary Intake: Very few significant differences for energy intake, protein, fat, and carbohydrate were evident between poor and non-poor, and all fell within recommended ranges. Differences in growth could not, therefore, be explained by measures of dietary intake. This may reflect methodological problems associated with using a 24-hour dietary recall method, which may not represent the habitual diet pattern of individuals (Jones, et al., 1985).

Bowering and Clancy (1986) analyzed NHANES II data on the vitamin and mineral intakes of children. They found the mean dietary intakes of these nutrients from food sources were above the Recommended Daily Allowances for all children under 12 years of age except iron intake for preschool children. Thirty-seven percent of 2 to 5 year old children were receiving vitamin and mineral supplements regularly. Greater use of supplements was associated with race (37% of whites versus 22% of blacks under 12 years of age), higher education level of parents, higher income (28% of the lowest income rank compared to 40% of the highest rank), and whether or not the mother took supplements.

Mahaffey, Gartside, and Glueck (1986), in their analysis of NHANES II data, found lower dietary calcium intakes in black children and children of low income levels. Lower calcium intake was also associated with high blood lead levels. Some nutrients, including calcium, modify lead absorption in infants.

Anthropometry: In general, children above the poverty level were found to be taller, heavier, and fatter, which finding is consistent with previous U.S. surveys. All race/sex groups showed higher mean heights for non-poor, but only 8 of 12 groups

were statistically significant. The differences between height of poor and non-poor children, ages 1 to 5, did not show any consistent changes between NHANES I and II. The difference for the 1 to 5 year age group was 1.3 centimeters in mean height between poor and non-poor. As in previous surveys, black children were taller than whites until adolescence.

Weight values also were higher in non-poor groups with the exception of the reversal in weights for adolescent females. Low-income females were heavier. Weight differences between poor and non-poor decreased in older age groups between NHANES I and II, but no significant changes occurred in the youngest children, ages 1 to 5 years. Poor children had 3 to 8% smaller skinfold measurements than non-poor, and the gap did not narrow significantly from the first to the second survey.

While there appears to have been a general improvement in growth of poor children from NHANES I and NHANES II, many of the differences do not reach statistical significance. The conclusion is, therefore, that growth differences associated with poverty, while improving, have not been eliminated.

Biochemical Values: Analysis of the data by an Expert Scientific Working Committee (1985) for the American Society for Clinical Nutrition found 9.2 to 9.4% of children, ages 1 to 2 years, and 6.1% of children, ages 3 to 10, with impaired iron; status. Black children showed a slightly higher prevalence, which was significant for 3 to 4 year old children. Poverty level children had a higher prevalence of low iron values, most notably in preschool children, ages 1 to 4 years.

Mean blood lead levels declined in NHANES II, but significantly higher levels were found in black children than white, ages 1 to 11 years, and in children from lower income levels and more urban areas. As previously stated, a significant inverse association between dietary calcium intake and blood lead levels was found (Mahaffey, et al., 1986).

In their analysis of vitamin and mineral use, Bowering and Clancy (1986) found users of supplements had higher mean serum levels of vitamins A and C and a lower incidence of low serum values for those nutrients than non-users. Fewer children took iron supplements than vitamin supplements. There were no significant differences in values for iron status or percentage of low values of iron status between iron supplement users and non-users.

Dallman, Yip, and Johnson (1984), estimated the prevalence of anemia from the results of NHANES II. The prevalence of anemia for all races, as defined by hemoglobin values below the 95% reference range for age and sex, was 5.7% in infants ages 1 to 2 years and 3.5% in 3 to 5 year olds. The values for all

races were very similar; however, there was a lower median hemoglobin concentration in blacks than in whites. Moderate or severe anemia was rare. Iron deficiency was the predominant cause of anemia in infants. The high prevalence of anemia in young children, who have increased iron requirements for rapid growth, is consistent with previous findings (Dallman, Siimes, and Stekel, 1980).

National Food Consumption Survey 1985

The National Food Consumption Survey (NFCS) provides data on the 24-hour dietary intakes of women, 19 to 50 years of age (n=1,503) and their children, 1 to 5 years of age (n=548). A comparable survey was done in 1977. In general, energy intakes in 1985 were reported to be higher, and intakes of all vitamins and minerals studied were as high or higher than reported in 1977. Exceptions were lower intakes of protein and fat. Children's intakes of food energy and nutrients were higher in 1985 than 1977 except for iron and zinc, which did not meet 1980 Recommended Daily Allowances (RDA) of the National Academy of Sciences' Food and Nutrition Board. For low-income families (below 130% poverty level), children were below RDA, regardless of race or income, for mean intakes of food energy (97% of RDA), calcium (96% of RDA), iron (84% of RDA) and zinc (76% of RDA). Food stamp participant children were below RDA only for iron and zinc.

RDA's are set high enough to meet requirements of nearly all healthy individuals. "Intakes less than RDA are not necessarily inadequate, but risk of inadequacy increases to the extent that intake is less than the recommended level." (NFCS, 1985). Use of RDA standards will classify significant numbers as "at risk" who may be consuming adequate diets (NFCS, 1985; Kerr, Lee, et al., 1982).

The tables on pages 9A and 9B show mean nutrient intakes of preschool age children as percentages of 1980 RDA and by income level and by race. Income levels are defined as a percent of the 1985 poverty guideline, U.S. Department of Health and Human Services.

Studies of Special Sub-Populations

Utah Nutrition Monitoring Project, 1985

The Utah Nutrition Monitoring Project (1986) surveyed 1,020 families in Utah whose income was below 185% of the 1985 poverty guidelines. A questionnaire format was used to obtain information on demographics, socioeconomic status, and use of existing income and food assistance programs. Additionally, a dietary history and anthropometric data were collected.

TABLE 1

NUTRIENT INTAKES OF PRESCHOOL CHILDREN BY INCOME AND AGE (% 1980 RDA)

	Number	Food Energy	Protein	Vitamin A	Ascorbic Acid	Thiamin	Riboflavin	Niacin	Vitamin B6	Vitamin B12	Calcium	Phosphorus	Magnesium	Iron	Vitamin E	Folacin	Zinc
0-75% Poverty																	
age 1-3	356	108	239	181	177	172	215	183	143	236	102	127	125	75	160	208	78
4-5	244	91	188	181	183	148	178	150	112	188	98	126	94	117	138	113	88
(Report 85-2)																	
76-130% Poverty																	
age 1-3	266	95	207	169	156	143	183	130	116	174	86	108	106	59	112	159	66
4-5	156	86	182	179	198	129	155	130	95	160	88	118	89	99	100	95	77
(Report 85-2)																	
131-300% Poverty																	
age 1-3	157	106	238	265	179	162	213	146	137	196	112	133	131	78	100	184	79
4-5	79	87	183	186	189	130	174	130	99	206	105	130	98	109	103	114	90
(Report 85-1)																	

TABLE 2
NUTRIENT INTAKES OF PRESCHOOL CHILDREN BY INCOME AND RACE (% OF 1980 RDA)

	Number	Food Energy	Protein	Vitamin A	Ascorbic Acid	Thiamin	Riboflavin	Niacin	Vitamin B6	Vitamin B12	Calcium	Phosphorus	Magnesium	Iron	Vitamin E	Folacin	Zinc
Children Ages 1-5																	
Low Income[1]:																	
White	839	100	215	178	175	152	198	147	124	198	102	126	114	84	121	154	75
Black	265	93	213	187	154	155	172	154	119	192	80	109	97	81	149	161	76
Other	162	94	211	168	209	144	170	141	114	186	84	116	103	87	121	148	76
All Incomes[2]:																	
White	457	100	217	214	182	150	196	147	126	181	106	132	121	84	99	152	78
Black	53	105	243	203	219	173	200	185	142	268	88	132	116	110	193	195	95
Other	24	98	251	233	200	160	188	157	128	236	100	132	122	85	96	181	156

[1] Equal to or less than 130% of poverty. Source: NFCS, 85-2.

[2] Source: NFCS, 85-1.

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Dietary Intake: The most frequently consumed foods were tabulated by age groups. In the preschool group breads were the most frequently consumed food followed by milk. In the fifteen most frequently consumed foods, there were no vegetables and only one fruit, bananas.

Nutrient intakes of children ages 1 to 5 years were listed by percent of Recommended Daily Allowances consumed. Table 3 shows the percent of children who consumed less than two-thirds of the RDA for that specific nutrient.

The levels of nutrient intakes of preschool children found in this study agree generally with the results of the NFCS, especially the high percentages of low iron and zinc intakes and the high levels of energy and protein intakes.

Anthropometry: In the preschool group, ages 1 to 5 years, 122 children were included. The following shows the percentages of these children under the 5th percentile and over the 95th percentile for different anthropometric measurements:

	AGES 1 - 5	
	<5th	>95th
Height-for-age	33.3%	17.9%
Weight-for-age	20.5%	12.8%
Weight-for-height	10.3%	12.8%

TABLE 3

Percent of Children < 185% of Poverty Below

Two-Thirds of RDA (Utah)

Energy	7.38
Protein	1.64
Vitamin A	5.74
Vitamin D	58.20
Vitamin E	36.89
Vitamin C	18.85
Folic Acid	23.77
Niacin	8.20
Riboflavin	3.28
Thiamin	4.92
Vitamin B6	22.13
Vitamin B12	9.02
Calcium	11.48
Phosphorus	5.74
Iron	45.08
Magnesium	12.30
Zinc	42.62

The most prevalent growth problem was short stature for age among one-third of these preschool children. About one-fifth are below the 5th percentile for weight-for-age. These data suggest there was more undernutrition than overnutrition in this population.

Massachusetts Nutrition Survey, 1983

Nutritional status was determined on a sample of 1,146 low-income preschool children age 6 months to 5 years 11 months who used community pediatric health care facilities. Overweight, short stature, and anemia were the most common nutrition-related problems observed. Findings identified 9.8% of the sample with low height-for-age levels, which is higher than previous U.S. survey findings, and 3.0% with low weight-for-height measurements. Of those children who had hematocrits assessed within six months prior to the survey, 12.2% were anemic. The prevalence of overweight was 8.1% of the population (Graham, 1985; Brown, Serdula, Cairns, et al., 1986).

Centers for Disease Control (CDC): Pediatric Nutrition Surveillance System, Annual Summary, 1983.

Data on 539,322 children from birth to 9 years of age were submitted to the Pediatric Surveillance System in 1983 (CDC, 1985). The children were enrolled in public programs including the Special Supplemental Food Program for Women, Infants and Children (WIC), the Early and Periodic Screening, Diagnosis and Treatment Program (EPSDT), and publicly funded Maternal and Child Health clinics. Since many more children are eligible for public services than actually receive them, surveys based solely on clients of these services may produce selection bias in the direction of underestimating nutrition problems.

Nutrition-related abnormalities were identified in 15.7 to 33.4% of the children, and multiple abnormal indices were identified in 1 to 5%.

Anthropometric Results:

Height-for-age: The most prevalent problem was short stature (height-for-age below the 5th percentile). In children 3 months to 5 years of age, the percentage (5.9 to 23.6%) below the 5th percentile was greater than the expected 5%. In children less than 6 months the percentage was greatest among blacks (5.3 to 16%). Over 6 months of age, the percentage was greatest for Asian children in each age group (13.4 to 23.6%).

Weight-for-height: Prevalence of low weight-for-height as a reflection of undernutrition was consistently below the expected 5% and was not considered a major public health problem. However, prevalence of overweight children was more

than the expected 5% of the population after 2 months of age. From birth to 5 years of age, overweight was most prevalent among Native Americans and Hispanics.

Hematology:

The prevalence of low hemoglobin was greatest among Asian children less than 2 years and blacks ages 2 to 5 years. The prevalence of low hematocrit was greatest among Hispanics ages 6 months through 5 years of age. Overall, there was a five year trend of a modest decrease in the prevalence of anemia as measured by hemoglobin for blacks, whites, Native Americans, and Asians. Trends in anemia as measured by hematocrit were more variable. The 2 to 5 year old age group had the greatest prevalence of low hemoglobin except for Native Americans, and the greatest prevalence of low hematocrit in all ethnic groups (CDC, 1983).

Pediatric Nutrition Surveillance System, 1986

Preliminary data were reported for 800,000 children under 60 months of age. Of these children 49.6% were white; 34.1%, black; 13.3%, Hispanic; 1.5% American Indian/Alaskan Native; and 1.0% Asian/Pacific Islander.

The prevalence of short stature was greater than the 5% expected. Asian children had the highest prevalence of short stature, which may reflect nutritional deficits as well as genetic factors (CDC, 1987). Prevalence of short stature was lowest among blacks except before one year of age when they had the highest prevalence, most likely reflecting a higher rate of low birthweight in this group. Low prevalence in this group after age one may reflect genetic differences for growth potential or improved nutritional status (CDC, 1987).

Overweight rates were also greater than the expected 5%. Rates were generally highest among Hispanic children. They were also prevalent among American Indians and Alaskan natives, although not to the extent observed in PNSS 1982.

The prevalence of underweight was less than 5% expected and tended to decrease with age in all groups except Asian/Pacific Islanders. Hispanics had the highest rates in the 0-11 month age group, and Asians, the highest rates in the older age groups (CDC, 1987).

More recent anemia prevalence rates reported by the Centers for Disease Control, Pediatric Nutrition Surveillance System, indicate a declining prevalence of anemia among low-income children in the U.S. from 7.8% in 1975 to 2.9% in 1985. Prevalence of anemia declined significantly for all age groups and all races. The difference between black and white children

narrowed, and American Indian children had a lower rate than either black or white. The anemia rate for each socioeconomic group declined with the lowest socioeconomic group showing the greatest decline over ten years. However, the authors state that very stringent cut-off values used to define anemia may have underestimated the prevalence. They state that "the prevalence of anemia among children ages 1 to 5 years from low income families in the mid-1980's probably is in the range of 6% to 8% based on less stringent cut-off values commonly used in clinical settings" (Yip, Binkin, Fleshood, et al., 1987, CDC, 1986a).

Yip, Walsh, Goldfarb, et al. (1987) noted a similar trend in middle-class children. The overall prevalence of anemia decreased from 6.2% in 1969-1973 to 5.8% in 1974-1977, 3.8% in 1978-1981, and 2.7% in 1982-1986. They concluded that iron deficiency is now mild and uncommon in these middle-class children.

Gayle, et al. (1987) examined the contribution of low birthweight (weight less than 2500 grams) to prevalence of low length-for-age by analyzing data from the PNSS on 374,544 children under 24 months of age. Overall rates for low birthweight in this sample were 9.2% for whites, 13.4% for blacks, and 9.2% for Hispanics. The mean prevalence of low length-for-age during the first two years of life was reported as 10.4% for whites, 12.0% for blacks, and 11.7% for Hispanics. The mean proportion of low length-for-age attributable to low birthweight was 28.9% for whites, 27.6% for blacks, and 21.3% for Hispanics. The authors believe that this demonstrates the need to consider the prevalence of low birthweight when reporting population estimates of malnutrition.

Memphis Survey, 1983

The nutritional status of preschool children from 1,219 families was studied. These families were living in an economically depressed area of Memphis which was also surveyed by the authors in 1977 and 1969. A comparison of the results of the three surveys indicated continuous improvement of serum levels of vitamins A and C, hemoglobin, hematocrit, and red blood cell volume. Improvements were attributed to increased enrollment in the federal food stamp program, an ongoing commodity supplementary foods program, and more children attending preschool programs (46% of 3 to 6 year old children) where meals or snacks were served. However, 9 to 18% of the infants and children had low or deficient levels of vitamins A, C, B1, B2, hemoglobin, serum iron, and transferrin saturation. Percentile distributions of heights and weights were similar between 1977 and 1983. Obesity or weight above the 95th percentile occurred in 10% of the children in 1977 and in only

4% in 1983 (Zee, DeLeon, Roberson, et al., 1985; Zee, et al., 1970).

Minnesota Survey, 1983

Ethnic group differences in nutritional status of preschool children were studied in a sample of 566 preschool children selected from low-income urban areas in St. Paul, Minnesota. Data were collected through interviews on demographic and economic characteristics and participation in public food and nutrition programs. Anthropometric and hematological evaluations were done. The sample had a relatively high educational level, most likely due to the participation of a high number of children of low-income university students, and their health risks may be different from a less educated poor population. Also, 28% of eligible households selected did not participate, so results may have been biased by selective participation.

Anthropometric Results:

About 13% of children had short stature and 15% were overweight. Only 1.8% were underweight. Southeast Asian children, especially foreign born, had a higher prevalence of short stature than any other ethnic group.

Hematological Results:

Approximately 4 to 7% of the children were anemic by the following criteria: low hemoglobin, 4.3%; low hematocrit, 6.9%; elevated erthrocyte protoporphyrin (EP) levels, 6.0%. A high prevalence of high EP levels occurred in Southeast Asian children. Low hematocrits and hemoglobin were higher (12.6% and 4.6% respectively) for children eligible but not participating in WIC, but the difference was not statistically significant (Brown, et al., 1986).

Studies of Hospitalized Children - United States

Merritt and Suskind (1979) conducted a nutritional survey of hospitalized pediatric patients at Children's Hospital Medical Center, Boston, Massachusetts, on a single day. Over one-third of the children exhibited evidence of acute malnutrition by virtue of weight-for-height below 90% of standard, and nearly half had chronic malnutrition by virtue of height-for-age less than 95% of standard (Waterlow, 1974; Waterlow, Buzina, Lane, et al., 1977). On head circumference measurements, 8% were more than two standard deviations below the median for age which may represent early nutritional insults.

The authors concluded that the prevalence of malnutrition in hospitalized pediatric patients is far higher than generally recognized. While many of the children in this survey had chronic diseases associated with poor growth, much of their growth failure could have been a result of malnutrition.

Listernick, et al. (1985) retrospectively studied 16 children, ages 18 months or less, previously admitted to Northwestern University Medical Center, Chicago, Illinois, for treatment of nonorganic failure-to-thrive (NFTT) due to environmental deprivation as opposed to disease. The degree of the severity of malnutrition had not been recognized in any of the children during their hospitalization. The authors state that under-recognition occurs in part from lack of awareness of proper nutritional assessment techniques. It also occurs because children in the U.S. who are seriously malnourished have usually not been involved in the health care services system. The usual nutritional surveillance systems do not identify them, and, therefore, they are only discovered when they need acute medical care. As a result, the authors recommend that estimation of the prevalence of severe malnutrition in the U.S. include hospital-based studies.

III. CONSEQUENCES OF ADVERSE NUTRITIONAL STATUS

A. Growth

Growth is the most widely used index in assessing nutrition in children. In healthy populations individual variation in growth is primarily determined genetically. However, when growth lags behind genetic potential, environmental factors have a major influence. Among these are nutrition, socioeconomic status, and infection or disease (Sutphen, 1985).

Growth Standards and References

The National Center for Health Statistics (NCHS) developed reference standards for percentiles of growth measurements based in part on data from NHANES I. These are the most commonly used standards in population nutrition assessments. The selection of reference standards and arbitrary cut-off levels to define low values raised several issues. Do these children have abnormal conditions, is their growth impaired by undernutrition or neglect, are they growing normally but have unusually small parents, or is their growth normal but with a slow rate of maturation. (Hamill, Drizd, Johnson, et al., 1979; Trowbridge, 1984)

The TSNS and NHANES I data showed race-specific and ethnic differences. Black children are taller and leaner than white children, and Hispanic children are smaller. These findings have suggested that race-specific growth references might be more appropriate. Kerr, Lee, Lorimer, et al. (1982), in their analysis of NHANES I data, concluded that parental stature, race, and SES must be considered when interpreting the growth of children before concluding that nutritional factors are the major determinants.

Trowbridge (1984) states that in "the developing countries, environmental factors are likely to outweigh genetic influences, but in industrialized countries, adverse environmental factors have been substantially reduced, and genetic factors may be relatively more influential."

The appropriateness of using NCHS percentiles, which were developed with well-nourished populations, for comparing children of less well-nourished developing countries with different ethnic and geographic backgrounds has been questioned. Habicht, Martorell, Yarbrough, et al. (1974) reviewed patterns of growth of preschool children from various geographic, ethnic, and socioeconomic backgrounds to determine if differences warranted the establishment of regional reference standards. They found that children grow rather uniformly in length and weight during the first 3 to 6 months of life. After 6 months of

age, children from developing countries lag behind those from developed countries. However, among well-nourished children in different countries, growth differences are relatively small. Comparisons of poor and non-poor children within the same ethnic population usually show that the non-poor children approximate the standards of developed countries. In 1981, Graitcher and Gentry compared growth data on privileged children in Egypt, Togo, and Haiti and also found growth status comparable with that of U.S. children. Olness, Yip, Indritz, et al. (1984) conclude that application of a single growth reference such as the NCHS standards is reasonable while taking into account the discrepancies of economically or nutritionally deprived children. They feel the reference may be regarded as the growth potential for these children.

Waterlow, et al. (1977) believe that the NCHS reference data can be used for comparisons between populations with adjustments of cut-off levels if necessary. They recommend the use of centiles in describing children from relatively well-nourished populations. In relatively undernourished populations standard deviation scores, instead of percentage deviation from the median, should be used. Two standard deviations from the median corresponds to approximately 80% of median weight for height and 90% of median height for age, recommended as useful limits for identifying significantly malnourished subgroups of children among populations characterized by undernutrition.

Definitions of Anthropometric Indices

Stature

The stature of children is assessed by measuring the supine length in children less than three years of age and the standing stature of older children. Normal stature varies widely among ethnic groups, but within each group it has a fairly normal distribution. Stature is primarily determined genetically and by rate of maturation. However, environmental factors including nutrition affect stature. "Height stunting" is a slowly developing phenomenon which reflects long-term chronic malnutrition. The extent of height deficit in relation to age reflects the severity and chronicity of malnutrition (Rimin, Borochowitz, and Horton, 1986; Sutphen, 1985; Waterlow, 1972; Waterlow, et al., 1977).

Height-for-age below the 5th percentile (NCHS) indicates need for follow-up of an individual child. When height-for-age is above the 10th percentile, but weight-for-height is below the 5th percentile, illness or nutritional deficit may be suspected (Hamill, et al., 1979). In undernourished populations, however, Waterlow, et al. (1977) recommended using 90% of the median

(50th percentile of the reference population) height-for-age to identify significant chronic malnutrition.

Growth velocity, or the rate of change in stature, is more sensitive to nutritional deprivation but requires serial measurements at one year intervals for most accurate comparison (Sutphen, 1985; Solomons, 1985; Tanner, 1976). A reduction in the rate of linear growth could appropriately be called retardation and reduction in final stature stunting (Waterlow, 1972).

Weight

Weight is expressed as weight-for-age or weight-for-height. Weight is subject to greater variations and more short-term changes than other measurements and can be misleading. Weight-for-height gives a more accurate estimate of current nutritional status which is independent of age and age-related external standards (Waterlow, 1972). Low values indicating "thinness" or "wasting" are considered to be a reflection of acute malnutrition (Sutphen, 1985). Both weight-for-age and weight-for-height less than the 5th percentile should lead to suspicion of nutritional deficiency (Hamill, et al., 1979). When expressed as percentage of median (50% percentile), 80% median weight is considered a low value (Waterlow, 1977).

Weight-for-height greater than the 95th percentile suggests obesity but is not diagnostic because it does not account for body composition. Children greater than the 95th percentile may have unusually good muscle development with little adipose tissue. Additional measures, such as skinfold measurements, are needed for diagnosis of obesity (Hamill, et al., 1979).

Skinfold Thickness

Skinfold thickness is determined most commonly by the use of special calipers over the triceps area of the upper arm or subscapular area of the upper back and then compared to NCHS reference charts. Although triceps skinfold thickness greater than the 85th percentile is used to diagnose obesity, there are questions if this accurately reflects the entire mass of subcutaneous fat and if this is an unvarying proportion of total body fat (Sutphen, 1985).

Upper Arm Circumference

Upper arm circumference represents muscle plus fat and bone. It correlates strongly with weight and decreases sensitively in response to malnutrition (Sutphen, 1985).

Head Circumference

Head circumference is thought to be relatively unaffected by malnutrition and, therefore, is not useful in screening for malnutrition. It is useful in screening for other medical abnormalities (Hamill, et al., 1979).

Dental Age and Bone Growth

Dental age or the emergence of teeth is a rough indicator of maturity between 30 months and six years of age, but is genetically dependent and relatively resistant to nutritional factors.

Bone growth is a measure of maturation and an important index of growth. It is measured by x-ray study of the ossification of bones, usually in the hand and wrist, which provide a large number of bones to examine. Rate of maturation varies and appears to be genetically determined. Girls have a faster maturation rate than boys, and blacks have advanced bone age relative to standards. Factors which delay skeletal growth (malnutrition, chronic infectious disease and chronic illness) also delay skeletal maturation (Rimoin, et al., 1986; Sutphen, 1985).

Bone growth is also thought of as a measure of growth potential. A child with delay of bone age and short stature is considered to have greater potential for catch-up growth than a short child with normal or less delayed bone age (Sutphen, 1985).

Long-term Implications: Ultimate Stature

Evidence from the NCHS data and data from other U.S. surveys show that undernourished children are often short in stature, and there is a clear relationship between family income levels and reduced height (Kerr, Lee, Lorimer, et al., 1982; Trowbridge, 1984). Studies from other countries show similar results for samples of preschool children of the same ethnic population but different socioeconomic groups (Habicht, et al., 1974).

There is no general agreement about whether growth retardation caused by malnutrition in early childhood is reversible or irreversible. Some follow-up studies of malnourished children indicate permanent stunting as a result of uncorrected chronic malnutrition. Other studies conclude that growth is delayed but "catch-up" growth is possible. Presently,

there is insufficient evidence to determine critical periods of growth or how extensive malnutrition must be to make catch-up growth impossible (Sutphen, 1985).

Alvear, Artaza, Vial, et al. (1986) compared 40 preschool children in Chile who had been hospitalized in infancy for malnutrition with 38 control group children of the same age, sex, and socioeconomic level who had never been malnourished. The malnourished group had a significant delay in stature after four years even though they experienced a compensatory acceleration of growth following rehabilitation. However, the shorter children had similar bone age to the control group which led the authors to conclude that some permanent growth limitation would occur.

Martorell, Yarbrough, Klein, et al., (1979) longitudinally analyzed the effects of a supplementation program on body size and skeletal maturation in preschool children in Guatemala. They found that chronic malnutrition affects stature to a greater extent than bone age or maturation. They concluded that when chronic malnutrition occurs, particularly during periods of rapid growth such as early childhood, it results in permanent growth stunting. Even when conditions improve, as in the supplementation program, the child is unable to catch up on all lost growth because the biological time and opportunity to grow has passed. Catch-up is related to the extent to which maturation is delayed and more "time" exists for growing.

Kulin, Bwibo, Mutie, et al., (1982) report findings of a study of pubertal growth and development of 600 adolescents in Kenya, half from a high socioeconomic urban group and half from an impoverished rural group. Significant differences in anthropometric measurements were found between the two groups just before the onset and during the early stages of puberty. Puberty also was delayed by three years in malnourished boys and by 2.1 years in malnourished girls. However, notable catch-up growth was seen throughout the later periods of adolescence.

Galler, Ramsey, and Solimano (1985), in a follow-up study of 216 Barbadian children, found delayed sexual maturation and growth deficits in 9 to 15 year old girls who had experienced a moderate-to-severe episode of malnutrition in infancy. In contrast, boys with a similar history were slightly reduced in height from the comparison group and had similar patterns of sexual maturation. However, growth velocity was similar for the index groups and comparison group for boys and even higher for index girls, implying that "catch-up" growth was possible.

Studies of low birthweight infants show significant growth differences which persist until 1.5 years for head circumference, 2 years for weight, and 3.5 years for length. Some follow-up studies have shown adequate catch-up growth, but

most have found some degree of persistent subnormal growth especially for smaller and sicker infants (Sutphen, 1985).

B. Health Status

There is strong evidence that height and other anthropometric measurements reflect nutritional status of children. However, Tanner (1976) states,

> We have to remember that the whole concept of 'nutrition' is an abstraction from a much more complex reality, which includes parasites, maternal behavior, the distribution of family income, the energy cost of older siblings, even the happiness and security of the child. So we are really discussing not nutrition, but micro-ecology, and not the monitoring of nutritional status, but of health itself.

Studies of the long-term consequences of malnutrition for health status have documented increased morbidity and mortality associated with poor growth. Chen, Chowdhury, and Huffman (1980) studied 2,019 children ages 13 to 23 months of age in a rural area of Bangladesh. Varying degrees of nutritional status were represented in the sample, from normally nourished, through mild and moderately malnourished, to severely malnourished. Severely malnourished children had a 3 to 7 times higher mortality risk, depending upon the classification system used. The mortality risk of mild and moderate malnutrition was not significantly different from that of normally nourished children. The classification systems investigated were weight-for-age, weight-for-height, height-for-age, arm circumference-for-age, arm circumference-for-height, weight quotient, and height quotient.* All indices discriminated mortality risk. However, weight-for-age and arm circumference-for-age were strongest and weight-for-height was weakest. Discrimination was increased when socioeconomic indicators and nutritional status of the child's mother were added to the data. Child mortality was consistently higher among children with lighter or shorter mothers and among children living in smaller housing units.

Sommer and Loewenstein (1975) followed 8,292 Bengali children between the ages of 1 and 9 years for 18 months after a nutritional assessment using arm circumference-for-height. Children at or below the 9th and between the 10th and 50th percentiles for arm circumference-for-height were at 3.4 and 1.5

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*"Weight quotient and Height quotient are the ratios of the weight-age or height-age of the child (the age at which the weight or height of the child is at the 50th percentile of the Harvard standard) divided by the child's chronological age" (Chen, et al., 1980).

times greater mortality risk, respectively, than those above the 50th percentile. The most vulnerable group was 1 to 4 year olds.

Kielmann and McCord (1978) reported similar mortality risks among 3000 children of Northern India, ages 1 to 36 months, who were classified by a weight-for-age index of risk. On average, mortality doubled with each 10% reduction of weight-forage below 80% of the Harvard weight median.

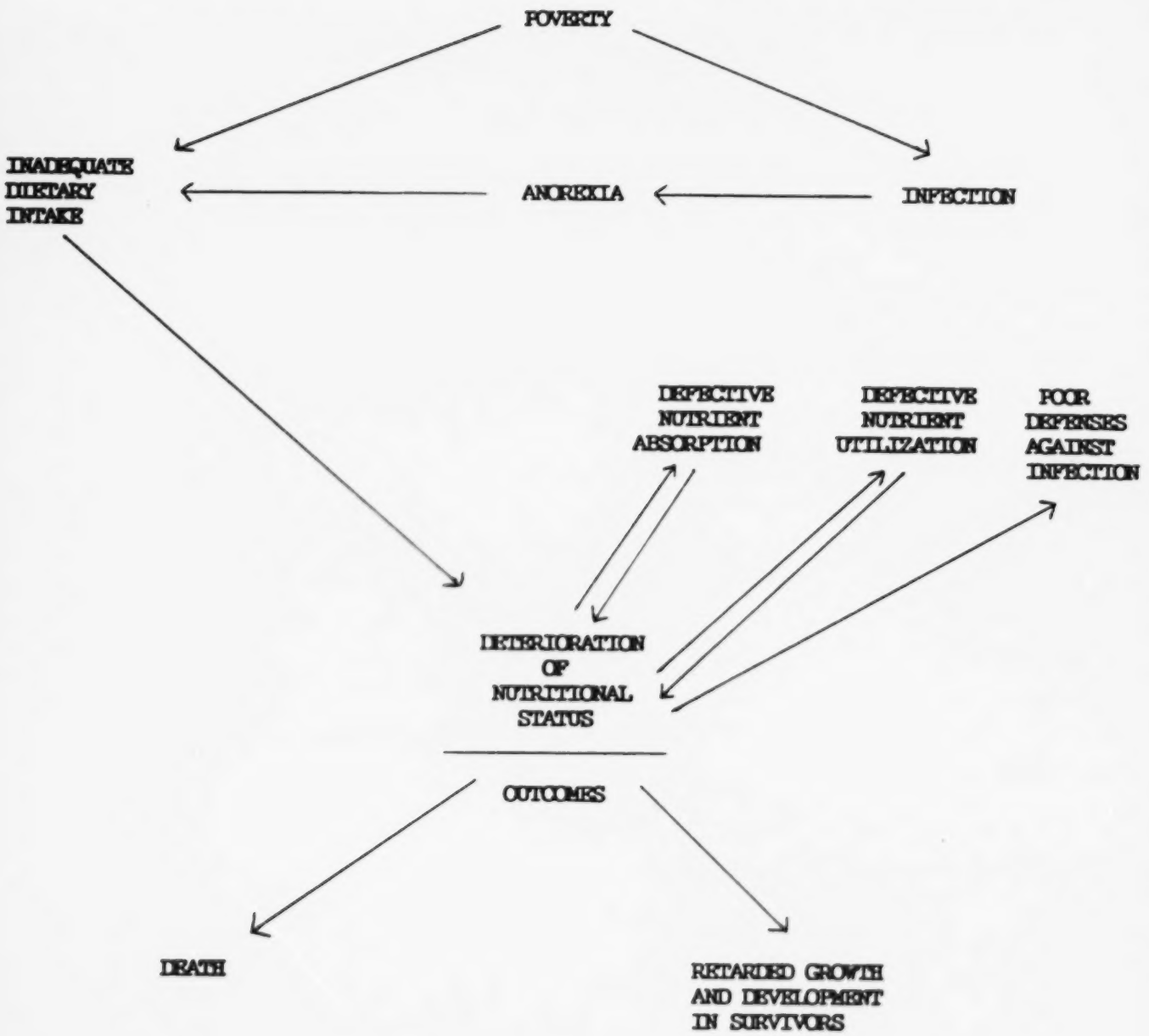
A one year longitudinal study was conducted by James (1972) of 137 children, ages 1 to 36 months of age in Costa Rica, 54 of whom were well nourished and 83 malnourished (classified by weight). Environmental and socioeconomic conditions were the same for both groups. The rate of diarrheal infections in malnourished children was twice that of normal weight children over one year of age, and the duration of the illness was significantly longer. The number of attacks of respiratory infections was the same in both groups, but the duration was longer and complications significantly more frequent in malnourished children. Twenty-four of the malnourished children versus two of normal weight required hospitalization during the course of the study, and 4 children died, all from the malnourished group.

C. Malnutrition and Infection

Infectious diseases occur more frequently, are more severe, and have longer duration in malnourished individuals. When infection and malnutrition occur simultaneously in the same child, as is frequently the case in developing countries, morbidity and mortality rates among children increase sharply, especially among impoverished children. Poverty limits the kinds and amount of food available and increases exposure to infection through poor environmental conditions. Infection affects nutritional status through adverse effects on appetite, nutritional absorption and utilization, and depletes nutritional stores. Poor nutritional status adversely affects the immune system, and consequently, increases susceptibility to infection. This interrelationship is diagrammed in Figure 1 on page 23A (Martorell, 1980).

In developing countries, common childhood illnesses, especially those involving diarrhea, have a profound effect on nutritional status. The coexistence of diarrhea and malnutrition leads to a self-perpetuating cycle. Diarrheal illness occurs more frequently in malnourished children and the attack rate correlates with the degree of malnutrition (Brunser, Figueroa, Araya, et al., 1984; Puri and Chandra, 1985).

FIGURE 1



THE BIOLOGICAL MECHANISMS THROUGH WHICH POVERTY AFFECTS NUTRITIONAL STATUS

Martorell, R. (1980). Interrelationships between diet, infectious disease, and nutritional status. In H.S. Greene and F.E. Johnston (eds). Social and Biological Predictors of Nutritional Status. Physical Growth and Neurological Development. New York:Academic Press.

However, the problems are not restricted to developing countries. Hospitalized children in North America frequently are malnourished, increasing their risk of opportunistic infections, complications during the course of their disease, increased hospital stay, and ultimately increased risk of mortality (Rundles, 1984; Puri and Chandra, 1985; Chandra, 1982).

Malnutrition impairs the body's defense mechanisms in a number of ways and may be regarded as the most common cause of acquired immodeficiency in the world today (Martorell, 1980; Chandra, 1981; Keusch, 1982). The effects may vary according to the age of the individual (infants and the elderly being more vulnerable), type and duration of malnutrition, specific nutrients which are deficient, nature of underlying disease, and concurrent infection. Most studies of the effects on immune response have involved cases of severe malnutrition. However, there is growing evidence that even mild to moderate nutritional deficits may adversely alter the immune response in a small proportion of undernourished children, often before clinical signs of malnutrition appear. This is supported by observations of reduced or delayed skin test hypersensitivity and other tests of immunological functioning (Ziegler and Ziegler, 1975). Immunocompetence is a highly sensitive indicator of nutritional status and would be a functional and practical way to assess the nutrition status of individuals and communities, provide prognostic information on hospitalized patients, and monitor response to treatment. Depression of immune response in malnutrition is generally reversible with appropriate treatment (Puri and Chandra, 1985).

Impairment may last longer if the nutritional deprivation occurred during gestation. Maternal malnutrition or infection during pregnancy may seriously impair the infant's immunocompetence. Children born prematurely may regain the immune response by three months of age. However, children small for gestational age who have experienced intrauterine growth retardation may continue to have reduced immune response several months or years after birth. This suggests that gestation may be a critical period in which the immune system may be particularly susceptible to nutritional deprivation (Miler, 1982; Chandra, 1984).

Postnatally, infant immunity is enhanced by breastfeeding, especially with early milk. Children in developing countries may do well during the first few months because of breastfeeding. Breast milk may later become limited in undernourished mothers, and supplements are often nutritionally inadequate or unhygenically prepared, resulting in illness and diarrhea (Martorell, 1980; Brunser, et al., 1984).

Studies of effect on individual nutrients have often resulted in conflicting data. Impaired host defenses can result

from excesses as well as deficits of single nutrients, and can occur alone or in combination with generalized malnutrition. Single nutrient deficits can lead to immunodeficiencies in individuals whose general nutritional status appears normal (Beisel, 1982; Chandra, 1981).

Iron deficiency effects are subject to debate but have been associated with increased incidence of infection even in sub-clinical deficiencies too small to lower hemoglobin. Deficiencies of zinc, magnesium, selected amino acids, vitamins A and E, folate, and pyridoxine also have been associated with altered immune responses. Excesses of vitamins A and E and of iron can impair responses also. A high intake of fat and hyper-cholesteremia appear to increase vulnerability to infection (Beisel, 1982; Chandra, 1981; Beisel, Edelman, Nauss, et al., 1981).

Overnutrition, which is a common type of malnutrition in developed countries, has been associated with increased susceptibility to infection and with altered immune responses. Obese persons may have single nutrient deficiencies, particularly zinc and iron (Beisel, 1982; Chandra, 1981).

D. Cognitive Development

The findings on effects of malnutrition on cognitive development and behavior have been inconclusive. Most studies have focused on outcome of severe malnutrition, but recently studies have been shifting to investigations of mild-to-moderate deficiencies. A major problem in reaching conclusions is the difficulty separating effects due to nutritional status from socioeconomic factors. An adverse environment is commonly associated with both malnutrition and delayed cognitive performance. Other difficulties include definition and measurement of malnutrition and of cognitive abilities (Ordonez, 1984; Grantham-McGregor, 1984). Controversy exists over whether initial effects of malnutrition are reversible. A majority believe that at least part of the damage is permanent depending upon the timing, severity, and duration of malnutrition. In a poor environment there is limited possibility for improvement, especially if diet continues to be deficient throughout life (Ordonez, 1984).

Severe Malnutrition Outcomes

The results of studies of children with previous episodes of severe malnutrition generally show delays in mental development.

In Chase and Martin's (1970) longitudinal study of Denver children, 19 malnourished in the first year of life compared to 19 well-nourished, results showed that the index group four years later had lower height, weight, head circumference, and developmental quotients. Those who were hospitalized after 4 months of age had lower scores than those who were hospitalized prior to 4 months of age and, therefore, malnourished for a shorter period of time. Language development was more severely impaired than other skills.

Hertzig, Birch, Richardson, et al., (1972) studied intellectual functioning of Jamaican school boys who had been hospitalized for severe clinical malnutrition during the first two years of life compared to siblings and classmates who had never been severely malnourished. Intellectual functioning measured by the Wechler Intelligence Scale for Children (WISC) showed lower scores for the index subjects compared to their siblings and classmates. They also found no association between intellectual level and age at which the children were hospitalized, which suggests that brain vulnerability is not limited to the first year of life.

In a follow-up report of the above study, Richardson (1976) found that the IQ's of the boys were also associated with their height at the time of testing and with a measure of social background and parent capabilities. Severe malnutrition in infancy, short stature (indicating malnutrition of long duration), and disadvantaged social background were all associated with low IQ score. Severe malnutrition occurring in the context of overall good history of growth and favorable social background had negligible effects on IQ. It appears from these findings that children who have suffered an episode of severe malnutrition improve remarkably in an enriched environment, but it is probable that some permanent impairment will result (Grantham-McGregor, 1984).

Hoorweg and Stanfield's (1976) comparison of Ugandan children who were hospitalized with malnutrition in the first two years with well-nourished controls found that the malnourished children fell significantly below the comparison group in anthropometric measurements and tests of intellectual and motor abilities. These effects were not related to the severity of malnutrition but were related to the duration as measured by height deficit.

Grantham-McGregor (1984) also found in a Jamaican study that developmental levels of children recovering from severe malnutrition were related to degree of short stature on admission to treatment but not to their degree of wasting or severity. These findings suggest that chronicity of malnutrition is probably a more important correlate of mental functioning than severity.

Galler, Ramsey, Solimano, et al. (1983) also reported lower IQ performance in school-age children in Barbados with histories of moderate-to-severe malnutrition in the first year of life, with girls having greater deficits than boys. Socioeconomic differences in this study were not significantly associated with reduced IQ's, in contrast to the previous studies. A follow-up study of these children four years later (Galler and Ramsey, 1987) again showed moderately impaired scores on WISC-R in association with early malnutrition and did not show any evidence of "catch up". A follow-up at 9 to 15 years (1987) using scores on Piaget's conservation tasks as a measure of intellectual functioning found that below age 14 there was a clear difference in performance between cases and controls, demonstrating a continuing developmental lag in previously malnourished children.

Undernutrition Outcomes

Cognitive Performance

The effects of mild-to-moderate undernutrition on mental development may be even more important as it affects so many more children in both underdeveloped and developed countries.

Evidence from intervention studies with nutritional supplementation provides some support for a causal relationship between nutrition and mental development. Freeman, Klein, Townsend, et al. (1980) found that a supplementation program in undernourished rural Guatemalen children significantly raised cognitive test scores of supplemented over non-supplemented children.

Waber, Christiansen, Ortiz, et al. (1981) also studied the effects of a nutritional supplemental program and/or a maternal education program on cognitive development of Bogota children. Both programs had significant but separate effects on development. Children who received nutrition supplements and, to a lesser extent, those who received the maternal education program performed better than those who did not receive the treatments. Nutritional supplements at any point during the first three years of life had a beneficial effect, which suggests that the first 6 months are not a critical period for supplementation.

Social Behavior

There have been fewer studies of the effect of malnutrition on social-emotional functioning than on cognitive development, but there has been a shift of emphasis recently. One reason is

that cognitive test performance is highly dependent on behavioral factors including attention, persistence, and selfconfidence. Secondly, literature on both animal and human studies associated malnutrition with behavioral symptoms of apathy, poor attention, reduced social responsiveness, and difficulty regulating emotional state and behavior. Third, there is some evidence that social-emotional competencies may be more vulnerable to nutritional deficits than cognitive skills (Barrett, 1984).

Galler, et al. (1983b), in a longitudinal study in Barbados, evaluated classroom behavior of children ages 5 to 11 years who previously had moderate-to-severe malnutrition in the first year of life. They found a significant increase (60%) of symptoms of attention deficit disorder: impaired attention, increased distractibility, poor school performance, poor memory, reduced social skills, and emotional instability in previously malnourished children. Follow-up at 18 years of age continued to show these symptoms which were associated with poor school performance and high drop-out rates (Galler and Ramsey, 1987). Environmental factors and IQ contributed little statistically to the behavioral deficits. Differences remained significant when children with low IQ's were excluded, which may be interpreted that social-emotional functioning is more vulnerable to nutritional insult than cognitive skills (Galler, 1987; Frank, 1984).

Barrett, Radke-Yarrow, and Klein (1982) studied the effects of nutritional supplementation on the social and emotional functioning of mild-to-moderate malnourished Guatemalan children. They found that high caloric supplementation from birth to two years was associated with high levels of social involvement with peers, both happy and angry affect, and moderate activity level at school age. Low supplementation was related to passivity, reduced involvement in group activities, dependency on adults, anxious behavior, low levels of happy affect, and inconsistent activity levels. Cognitive processes were weakly affected by nutritional history, which again suggests that cognitive processes may be less vulnerable to effects of chronic malnutrition than social-emotional functioning.

Development of social skills appears to be dependent on learned interaction skills in the earliest stages of childhood and on caregiver-child interaction. It has been observed that undernutrition produces increased apathy and reduces children's activity levels and exploring, which may in turn reduce mother's responsiveness and enthusiasm toward the child. The child who does not elicit positive responses learns to withdraw from social contacts (Grantham-McGregor, 1984; Barrett, 1984).

Barrett and Radke-Yarrow (1985) examined the same Guatemalan children for effects of undernutrition on specific

task performance which required attention, persistence, impulse control, and the ability to perform under mild stress. Well supplemented children showed more exploration, greater adaptability to frustration and stressful situations, more involvement in a competitive game, and better impulse control. They concluded that supplementation effects increase the child's ability to seek out stimulation and respond to the environment. However, from analysis of social background data, the specific behavior patterns that emerge are shaped by the social and cultural environment, role models, and behavioral norms and expectations. The study found that boys and girls, who are socialized differently, are affected differently by the supplementation (Barrett, 1984; Barrett & Radke-Yarrow 1985). It is significant from this work that chronic undernutrition of mild-to-moderate severity predicts impaired social-emotional functioning. This level of malnutrition is far more prevalent, and would, therefore, put large numbers of children at risk of social dysfunction (Frank, 1984).

Iron Deficiency: A Special Case

Micronutrient deficits alone or in combination with generalized malnutrition may be confounding the relationships between nutritional history and cognitive or behavioral functioning. Iron deficiency, which is relatively prevalent and easily measured, has been extensively studied for its effects (Frank, 1984).

Results of NHANES II, 1976-1980, indicated that the prevalence of anemia was 5.7% among infants (all races), and 3.5% among 3 to 5 year olds (all races). Black children, ages 3 to 5, had a slightly lower mean hemoglobin concentration than white (Dallman et al., 1984). More recent prevalence rates reported by the CDC, Pediatric Nutrition Surveillance, are in the range of 6 to 8%. (Yip, Binkin, Fleshood, et al., 1987).

Pollitt, Saco-Pollitt, Leibel, et al. (1986), in their own studies and reviews of the literature, find evidence that strongly supports an association between iron deficiency, with or without anemia, and behavioral symptoms of apathy, inattentiveness, irritability, and memory difficulties. They also find lowered performance on cognitive tests in infants and preschool children, although there is no evidence of the specific mental skills that may be affected. With iron repletion treatment over 7 to 10 days, they found improvement in Bayley Mental Development Index in infants, with and without anemia. However, in populations where severe protein-energy malnutrition has high prevalence, poor cognitive test performance in iron deficient children may fail to improve following iron treatment. These children also tend to be

smaller and lighter than children without iron deficiency (Pollitt et al., 1986; Pollitt, 1985).

Oski and Honig (1978) and Oski, Honig, Heln, et al. (1983) also found an association between iron deficiency and impaired performance of infants on the Bayley Scales of Infant Development in two studies: one with children with anemia and one with children, iron deficient, but not anemic. Treatment with intramuscular injections of iron produced significant improvement in test performance within one week of administration in both studies.

Walter, Kovalskys, and Stekel (1983) studied cognitive function in iron deficient infants, with and without anemia, in Chile, as measured by the Bayley before and after 11 days of treatment with orally administered iron. The group with deficiency but not anemia, did not show statistically significant improvement except among those diagnosed by two or more deficient biochemical measures. The anemic children improved their scores significantly. This was attributed to improvements in attention span and cooperativeness during the test. The authors conclude that mild iron deficiency has an effect on behavior which is rapidly reversible with iron therapy.

Deinard, Gilbert, Dodds, and Egeland (1981) did not find a relationship between iron depletion and cognitive development or attentional behavior among iron deficient non-anemic children ages 11 to 13 months in Minneapolis. A more recent study by Deinard, List, Lindgren, et al., (1986) evaluated 18 to 60 month old children, iron deficient, with and without anemia, who were treated with iron and their performance compared to normal controls. The experimental groups showed corrected iron levels but no significant changes in Bayley developmental scores at 3 months and 6 months after treatment. Behavioral ratings of responsiveness and emotional tone, however, showed the normal controls to be more responsive than anemic children.

Lozoff, Brittenham, Viteri, et al. (1982) studied Guatemalan infants, 6 to 24 months of age, with and without anemia, who were tested before and after one week of oral iron treatment. The anemic groups showed significant developmental deficits both before and after treatment. Iron therapy did not improve test scores as in previous studies, although hemoglobin levels had increased to the expected level. Lozoff also investigated the influence of age on the difference in performance between anemic children and controls. The group differences were primarily in the older infants, age 19 to 24 months, which suggests that certain test items may be more sensitive to the effects of anemia. These are social and language items which increase with age on the Bayley Scales, while sensorimotor items

are presented to younger infants. The older infants were also somewhat smaller and may have been in poor health.

Finally, Palti, Meijer, and Adler (1985) reported results of a prospective study of learning achievement and classroom behavior of second grade Israeli children who had been anemic and corrected at 9 months of age as compared with never anemic, same age children. The mean score on learning achievement and on positive task orientation was significantly higher for children who were not anemic in infancy. The previously anemic children showed distractibility, lack of discipline, and restlessness. The authors believe that their findings suggest an iron deficient state during critical periods of brain development in infancy may have long-lasting effects on cognitive function and behavior.

Lead Levels and Behavior

Needleman (1983) compared cognitive and behavioral functioning of children with high and low lead levels, classified by lead levels in teeth, believed to be an accurate measure of past lead exposure. The results showed that high lead levels were associated with deficits in IQ, verbal IQ, auditory processing, and attentional performance. Teacher ratings of high level subjects were negative twice as frequently. A sub-sample was found to have changes in electroencephalogram examination compared to low level subjects. High lead subjects, three years after the initial study, were observed to spend more time in distracted, off-task behavior in the classroom.

Lead and other heavy metals are absorbed more readily in malnutrition and in iron deficiency anemia, and the low socioeconomic population experiences higher risk of both (Yip, Binkin, Fleshood, et al., 1987; Bithoney, 1986). According to statistics from NHANES II, 4% of children, 6 months to 5 years, or 675,000 children, had elevated blood lead levels (Mahaffey, Annest, Roberts, et al., 1982). Of these, 2% of white children, 12.2% of black children, and 18.6% of inner city, black children in families with incomes below $6,000 had elevated blood lead levels (Mahaffey et al., 1982). Analysis of the trend in blood lead levels from 1976-1980 indicate a decrease of average blood lead levels of all age groups of approximately 37%. This parallels the decrease in the sale of leaded gasoline (Annest, Pirkle, Makuc, et al., 1983).

E. Obesity

Obesity is the "most prevalent and serious nutritional disease in the U.S." (Dietz, 1983). Reports indicate that the prevalence of obesity in children and adolescents may be from 5

to 25% (Dietz, 1983). Recent analyses of data from four national surveys (National Health Examination Survey 2 and 3, 1963-1970; NHANES I and II, 1971-1980) indicate substantial increases in the prevalence of obesity (54% increase among children ages 6 to 11) and superobesity (98% increase among children ages 6 to 11). Obese children are defined as those with triceps skinfolds greater than or equal to the 85th percentile, and superobese are those greater than or equal to the 95th percentile of children of the same age and sex. The estimated prevalence among children ages 6 to 11 in 1980 was 27.1% for obesity and 11.7% for superobesity (Gortmaker, Deitz, Sobol, et al., 1987). By contrast, our own preliminary analysis of preschoolers indicates superobesity ranging from 2% for two to three year old males at or below poverty to 9% for four and five year old females at or above 185% of poverty.

The causes of obesity in children appear to be very complex. The relative roles of overeating and underactivity have been the subjects of extensive study and debate. In several studies, energy intake and proportion of calories from fat and carbohydrates between obese and nonobese children was not found to differ significantly (Nuutinen and Knip, 1984; Dietz, 1983). The results suggest that overeating does not play an important role in the maintenance of childhood obesity which, once established, persists on a normal energy intake rather than on increasing food consumption (Nuutinen and Knip, 1984).

The importance of underactivity in the development of obesity has been supported by several studies. Lower levels and lower intensity of physical activity have been observed in obese children, although energy expenditure may be comparable to the nonobese because more work is required to move increased body mass (Walberg and Ward, 1983). Relationships have been found between the numbers of hours of television viewing and obesity in children (Gortmaker, et al., 1987). Differences in activity levels can be identified in infancy with obese babies being quieter, more placid and consuming a moderate intake of food as compared to thinner babies who are more active, tense, and with increased amounts of crying and greater food intake (Richmond, Blyler, and Linscheid, 1983).

Prevalence of obesity is associated with several environmental variables. Prevalence is greater in the Northeast U.S., followed by the Midwest, South, and West, and it is increased in winter and spring. Obesity prevalence is greater in densely populated urban areas than in rural areas (Dietz, 1983; Gortmaker et al., 1987). Obesity is more prevalent among whites and rises with income with the exception of upper-income women, who are leaner. Mothers' low education level is associated with increased prevalence (Dietz, 1983, 1986; Garn and Clark, 1976).

Family variables appear to be very important determinants of childhood obesity. Parental obesity, especially of both parents, is highly correlated with child obesity. If one child in a family is obese, the chances of an obese sibling are 40 to 80% (Garn and Clark, 1976). These data suggest genetic determinants. This is supported by an adoptive study by Stunkard, Sorenson, Hanis, et al. (1986), who found a strong association between body mass of adopted children and their biologic parents and no relationship with body mass of their adoptive parents. Other adoptee studies have shown the reverse (Garn, Bailey, and Higgins, 1976). Also, genetic causes do not explain significant relationships of obesity between spouses and between pets and their owners (Dietz, 1986). Garn and Clark (1976) conclude that familial fatness is due primarily to family similarities in caloric intake and expenditure and attitudes regarding food and eating.

Obesity is inversely proportional to family size and is most prevalent in single children. Younger children are at greater risk of obesity. Mothers and fathers of obese children are older, and separation from mother and parental deaths may be more frequent, as are divorce and parental separation (Dietz, 1983, 1986).

Immediate Health Consequences of Obesity

Hypertension

Strong associations between obesity and elevated blood pressure were found in the surveys previously cited for both younger children and adolescents (Gortmaker, et al., 1987). The Bogalusa Heart Study, which examined 2230 children, including 714 preschoolers, in 1973, 1976, and 1978, also showed significantly higher systolic blood pressures for obese and very obese children and higher diastolic blood pressure for the very obese children (Lauer, Anderson, Beaglehole, et al., 1984).

The available evidence suggest that both genetic and environmental factors contribute to elevated blood pressure in the young. Children of hypertensive parents are more likely to have elevated blood pressure in childhood. Obesity in children is associated with higher blood pressure levels, and adolescent weight gain is associated with development of hypertension. Blood pressure readings in childhood, which increase with physical growth and physical maturity, and tend to plateau after sexual maturation (Watkins and Strong, 1984; Lauer, et al., 1984; Szklo, 1986).

One factor that may contribute to hypertension in susceptible individuals is excessive salt intake. It has been suggested that salt intake in U.S. children is high, given

excessive consumption of high sodium snacks and fast foods (Watkins and Strong, 1984).

The question whether obesity in children is a risk factor for adult hypertension remains unanswered. Obesity and hypertension are strongly associated in adults, and hypertension in adults is a major cause of cardiovascular disease. There is increasing evidence that "the precursors of essential hypertension, although usually not manifest until adolescence or adulthood, are present in the young. Children with blood pressure above the 90th percentile for age are likely to become adults with elevated pressure" (Behrman and Vaughan, 1987).

Hyperlipidemia

Obesity in children is also associated with elevated low-density lipoproteins (LDL) and reduced high-density lipoproteins (HDL), although the association is weak. LDL carries cholesterol into cells and HDL helps rid the cells of excess cholesterol. An elevated LDL level is harmful and in adults is associated with cardiovascular disease. HDL levels are inversely related to heart disease (Deitz, 1986; Roy and Galeano, 1985; Aristimuno, Foster, et al., 1984).

Pathologic changes that lead to atherosclerosis may begin in infancy, with the appearance of fatty streaks in the aorta, and progress during childhood. However, the importance of fatty streaks and their transition to more advanced atherosclerotic lesions remains controversial (Roy and Galeano, 1985; Newman, Freedman, Voors, et al., 1980, 1986).

Lowering of dietary cholesterol has been shown to reduce the incidence of heart disease in adult men in the Lipids Research Clinics Program, 1984. The subject of dietary changes for children is controversial, as the reduction of foods containing cholesterol could compromise the nutritional adequacy of the diet for growth and development. There is no information now that dietary reduction of cholesterol in childhood decreases risk of heart disease (Roy and Galeano, 1986; American Academy of Pediatrics, 1986; Mallick, 1983; Starfield and Budetti, 1985).

Other complications of obesity in children related to the cardiovascular system include decreased stamina and exercise tolerance with poor heart rate recovery following moderate exercise, decreased heat tolerance, and decreased ventilatory ability (Richmond, et al., 1983; Williams, 1983-85).

Hyperinsulinemia

Abnormalities in carbohydrate metabolism and impaired glucose tolerance are common in obese children and adolescents, are related to the severity of the obesity, and are reversed by weight reduction (Deitz, 1986).

Orthopedic Conditions

Obesity is related to some childhood orthopedic conditions. Slipped capital femoral epiphysis, a rare condition, is one in which many of the patients are obese. Obesity also contributes to Blount's disease, congenital hip dislocation, and severe bilateral genu varum (Dietz, 1981).

Respiratory Infections

A study of children under 2 years of age reported an increased incidence of respiratory infections among those whose weight was greater than the 90th percentile or whose weight-for-height was greater than 120% of ideal weight (Tracey, De, and Harper, 1971).

Psychosocial Consequences of Obesity

Psychosocial dysfunction has been described as an important consequence of childhood obesity in this culture which values slimness and communicates discriminatory and prejudicial messages about obese persons. Children may suffer more than anyone from peer teasing and bullying (Taitz, 1983). Children as young as preschool age consistently rank obese children among those they least want as friends (Dietz, 1981, 1986). The obese child hesitates to participate in sports and the obese adolescent hesitates to participate in social events (Richmond, et al., 1983).

Some psychological studies comparing obese and nonobese children have not shown differences in adjustment, happiness, or self-concept (Kaplan and Walden, 1986). When using measures of socialization, however, Dietz believes substantial differences exist, especially in feelings of popularity or self-consciousness (Dietz, 1981).

It is also possible that obese children do less well academically. It has been found that there is a lower than expected proportion of obese individuals in U.S colleges. It is also possible that colleges discriminate against obese applicants (Taitz, 1983).

Long-term Consequences of Obesity

Risk of Adult Obesity

Obese children and adolescents are at increased risk of adult obesity with percentages depending upon age at diagnosis and degree of obesity. For infants and preschool children who are simply obese the risk of adult obesity is a little less than twice expectancy. For a superobese child the risk is 3 to 4 times expectancy. The probability is that 25% of obese infants will become an obese adult (risk ratio = 1.77), and 50% of obese adolescents will become obese adults. The probability increases as the number of obese family members increases (Garn and LaVelle, 1985).

In studies reviewed by Dietz (1981) the probabilities of obesity persisting into adulthood are 24% for obese 3 month olds, 54% for obese 11 year olds, and approximately 80% for obese 16 year olds. Adults with onset of obesity in childhood or adolescence are fatter than those with onset in adulthood (Dietz, 1981, 1986).

Epstein, Wing, and Valoski (1985) present similar figures based on their review of studies. The percentage of obese children becoming obese adults is 14% for obese 6 month olds (risk ratio=2.33), 41% for obese 7 year olds (risk ratio=3.73), and about 70% for obese 10 to 13 year olds (risk ratio=6.55). Once established, childhood obesity seems to be very resistant to treatment, making prevention very important.

Risk of Adult Obesity for Later Cardiovascular Disease

The major risk factors in adults for cardiovascular disease are hyperlipidemia, hypertension, and smoking. Other factors, of perhaps lesser influence, are sedentary living habits, obesity, hyperglycemia, psychosocial tension, and a positive family history of a premature (at less than 60 years of age) atherosclerotic event (Strong 1978).

The association between obesity and heart disease is less than that of other major risk factors. The existing risk is attributable to the association of obesity to hyperlipidemia, hypertension, and hyperglycemia rather than to obesity per se (Strong, 1978). The association between overweight and risk consist of a series of thresholds over which sharp increases of risk occur. Weight must exceed ideal weight by 25% before it becomes a significant risk. There is a very sharp increase in mortality when excess weight rises from 30 to 50% above ideal weight, with men more affected than women (Taitz, 1983).

Other Health Risks In Obese Adults

Over 65% of obese adults have impaired glucose tolerance, and more than half of patients with adult-onset diabetes are obese (Dietz, 1981). The prevalence of diabetes is 4 to 7 times more common in obese adults than nonobese (Andreoli, Carpenter, Plum, et al., 1986). One of the main consequences of diabetes is a higher risk of premature atherosclerosis (Strong, 1978).

Several other debilitating conditions affect obese adults. Obstructive lung disease is more common. Gallbladder disease is 3 times more common in obesity. Thrombophlebitis and pulmonary emboli occur more frequently. Osteoarthritis commonly affects weight bearing joints in obese persons who exceed 130% of ideal weight. General anesthesia and surgery carries much higher risk (Andreoli, et al., 1986). Obesity in pregnancy increases risk of toxemia, hypertensive disorders, and diabetes (Danforth and Scott, 1986).

Generally, obese people are disadvantaged in all areas of life. They experience discrimination in employment and personal relationships which frequently results in depression, feelings of rejection, and loss of self-esteem (Rubenstein and Federman, 1987).

How dangerous is childhood obesity? There remain too many gaps in knowledge and controversy over long-term consequences to answer that question. Taitz believes there is justification for concern that three risk factors in obese children may persist into adulthood: raised total cholesterol, lowered HDL cholesterol, and elevated blood pressure. Just how great the risk and its precise relationship to obesity remain unanswered. However, Taitz states that "every extra kilogram of weight takes 60 to 80 days off an average life. Thus, a child destined to become an adult who is 50 kilograms over ideal weight is likely to die ten years early" (Taitz, 1983).

IV. DISCUSSION

Recent concern with the nutritional status of Americans may be said to have been ushered in by the landmark report, Hunger, U.S.A. Although itself an anecdotal account of evidence of malnutrition among America's poorest children, the authors' medical testimony in Congress, coupled with widespread media attention, led to increasingly more scientific studies of the nutritional status of preschoolers and others.

The Ten-State Nutrition Survey was one such follow-up, focusing specifically on states and areas of the country likely to be home for poorer Americans. The Preschool Nutrition Survey, and the two National Health and Nutrition Examination Surveys, were sample surveys intended to be representative of a cross-section of all pre-school children in the first case, and of Americans of all income brackets in the latter two cases. Despite these differences, there are many conclusions which may be drawn that seem to be supported by these four studies, and from the National Food Consumption Survey, whose purview is limited to dietary intake.

It is clear that nutritional status is related to income, and that that relationship is in the expected direction. Poor children were observed to have poorer dietary intakes, not in terms of the relative quality of their diets, but in terms of quantity. Lower energy intakes among poorer children were observed by the Ten State Nutrition Survey as early as 1968, and again in the National Food Consumption Survey of 1985. Other observations among the five surveys included inadequate calcium, zinc, vitamin A and vitamin C intakes among the poor and/or among blacks, and inadequate iron intakes among all income groups, particularly among blacks.

Anthropometric findings are perhaps less straight-forward. In general, poor children tend to be shorter, but, beyond the age of two, black males, on average, tend to be taller. Within the population of black males, however, the same relationship between poverty and short stature is revealed. In some cases the burden of short stature is excessive. In the Utah Project, for example, 33.3% of children below 185% of poverty fell below the fifth percentile for height-for-age, 28.3% more than expected (Utah, 1986). Similarly, poor children are lighter and less fat than non-poor children, except for poor adolescent or black adolescent females, who seem in some studies to be heavier. There was no significant improvement in the gap in overall growth parameters between poor and non-poor preschoolers from NHANES I and NHANES II in the one study that examined them (Jones, et al., 1985).

Significant findings are consistently found among biochemical and hematologic measures. Poor preschool children

had greater rates of impaired hemoglobin and hematocrit levels, and poor black preschoolers had the most impairment. By the NHANES II era, there was improvement noted in iron or hematologic status, yet some impairment persisted. Similarly, elevated lead levels decreased from NHANES I to NHANES II, yet even by the time of NHANES II the incidence of elevated lead levels was over 18 percent among inner-city black children (Mahaffey, et al., 1982).

In this review we have chosen to examine some more controversial consequences of poor nutrition, namely, obesity and socio-behavioral problems. Obesity seems to be a problem among adolescent females, including poor adolescent females. Although a comparative study of older children has argued that obesity increased from NHANES I to NHANES II, no similar study of preschool children has been attempted. Our own preliminary analysis suggests that obesity may be a problem for females as young as age four or five, but these results must be interpreted as tentative at best. Although the younger the age, the less likely that childhood obesity will lead to adult obesity, the fact that childhood obesity is increasing implies that the risk of adult obesity, with associated health problems such as hypertension, hyperlipidemia, and impaired glucose tolerance, may also be increasing. The fact that obesity appears to be a particular problem for poor adolescent and for black adolescent females raises important policy issues about the quality of the diets of some of these girls and the role publicly supported nutrition programs could play in helping to solve this problem.

Even more difficult is the issue of the potential behavioral consequences of mild-moderate undernutrition among preschoolers. In the case of iron status, most, but not all, of the evidence suggests that impaired iron status, even in the absence of anemia, is associated with poorer performance on standardized tests, and that performance can be improved with iron therapy. Similarly, relatively recent studies, none of which were conducted in the United States, have produced good evidence of an association between nutrition supplementation of mild to moderate undernourished (as opposed to severely malnourished) preschoolers and improved social behavior. Supplemented children had better attention spans, more persistence, less distractibility, more social interaction, less dependence and anxiety, better impulse control and happier affect. The net effect of these improvements resulted in better performance in novel environments, more involvement in competitive games, greater number of strategies attempted in response to a frustrating task, and fewer errors in structural impulse control games. These results, were they reproducible in a North American population, would have important implications for the school performance of mild-to-moderately undernourished preschoolers.

V. PROGRAM EFFECTS

With a few exceptions the studies reviewed do not directly address program effects. This is more a consequence of the nature of the studies selected for review than a reflection of the efficacy of public food and nutrition programs. Although failure in one study to find improved growth parameters for preschoolers between NHANES I and NHANES II may be disappointing (Jones, et al., 1985), since program participation was not analyzed it cannot be concluded that program participation has had no effect.

Two of the studies that we did examine have more positive implications for program effects. The National Food Consumption Survey compared poor children on food stamps with those not on food stamps. Non-food stamp participants had four dietary micronutrient deficiencies, and food stamp participants had only two. However, one cannot conclude that food stamp participation caused the improvement because of the nature of the survey. In Memphis, researchers compared preschool nutrition status in 1977 and again in 1983 and noticed improvement in vitamin A and vitamin C intake, in hemotologic status, and in obesity. These improvements were attributed to increased participation in publicly supported food and nutrition programs.

In searching for surveys describing the nutritional status of preschool children, we did find articles describing improved nutrition status associated with participation in food programs. In the course of conducting a nutrition survey among randomly selected households with children under five years of age, Brown and Tieman (1986) found low income associated with low energy, iron, and vitamin C intakes, but WIC participation improved iron intake. Meals consumed by Maine children in Head Start improved their nutrient and energy intake. Their hematologic status also improved between the fall and the spring, but they still had not caught up with middle and upper middle class children attending nursery school (Cook, Davis, Radke, et al., 1976; Cook, Hurlburt, and Radke, 1976). In a comparison of former Head Start participants and non-participants eligible for free school lunch in public school, the Head Start graduates were taller, more physically fit and absent less from school (Gietzen and Vermeersch, 1980). Both these studies, however, are limited in their generalizability by virtue of small sample size (Cook, et al. 1976) and retrospective design (Gietzen and Vermeersch, 1980).

There has been overall improvement in the iron status of preschool children between NHANES I and NHANES II. It is likely that this improvement is attributable to iron fortification of infant formulas and cereal products (Yip, Walsh, Goldfarb, et al., 1987). Yip and colleagues also noted important gains in iron status in several states participating in the Pediatric

Nutrition Surveillance System (Yip, Binkin, Fleshood, et al., 1987). Observing that children already enrolled in the WIC program have better iron status than same-age children at their first WIC visit, the authors conclude that participation in WIC is associated with lower rates of anemia. Yet, even this gratifying result lacks the rigor of a scientifically designed prospective study. Further review of evaluation studies is beyond the scope of this paper. Suffice it to say that WIC, arguably the most thoroughly evaluated social program available to poor women and children, has survived periodic Congressional scrutiny by virtue of the preponderance of evidence in favor of its efficacy.

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